CS6504

Mobile Computing

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Channel Allocation Schemes

Outline

- [KN96] Channel allocation in cellular systems
- [PSS99] A sample Distributed Dynamic Channel Allocation Scheme

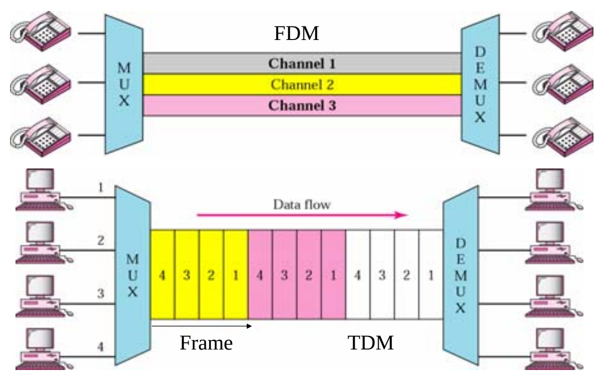
Channel allocation 1/5

- Appropriate when connections are long-lived
- A given radio spectrum can be divided into a set of disjoint or non-interfering radio channels
  - ➢FDM Frequency division (disjoint frequency bands)
  - ➢TDM Time division (time slots)
  - ➢CDM Code division (different modulation codes)
  - ➢Or a combination of the above (TD and FD for example)

➢Propagation path-loss in radio environment. Average power received from a transmitter at distance d is proportional to $P_T\, d^{-\alpha}$

- ➢α number in the range of 3-5 depending on physical environment
- ➢P_T is the average transmitter power
- ➢Assume α is 3.5 (indoor) what happens when distance becomes $2d$?

Channel allocation 2/5



Channel allocation 3/5

Code Division Multiplexing

- An advanced technique that allows multiple devices to transmit on the *same* frequencies at the *same* time.
- Each mobile device is assigned a unique 64-bit code (chip spreading code)
  - ➢To send a binary 1, mobile device transmits the unique code
  - ➢To send a binary 0, mobile device transmits the inverse of code
- Receiver gets summed signal, multiplies it by receiver code, adds up the resulting values
  - ➢Interprets as a binary 1 if sum is near +64
  - ➢Interprets as a binary 0 if sum is near –64

Channel allocation 4/5

Code Division Multiplexing

- For simplicity, assume 8-chip spreading codes
- 3 different mobiles use the following codes: Mobile A: 10111001
- Mobile B: 01101110, and Mobile C: 11001101
- Assume Mobile A sends a 1, B sends a 0, and C sends a 1

- Signal code: 1-chip = +N volt; 0-chip = -N volt
- Three signals transmitted:
- -Mobile A sends a 1, or 10111001, or +-+++--+
- -Mobile B sends a 0, or 10010001, or +--+ ---+
- -Mobile C sends a 1, or 11001101, or ++--++-+
- Summed signal received by base station: +3, -1, -1, +1, +1, -1, -3, +3

Channel allocation 5/5

Code Division Multiplexing

- Base station decode for Mobile A:
  - Signal received: +3, -1, -1, +1, +1, -1, -3, +3
  - Mobile A's code: +1, -1, +1, +1, +1, -1, -1, +1
  - Product result: +3, +1, -1, +1, +1, +1, +3, +3
  - Sum of Product results: +12
  - Decode rule: For result near +8, data is binary 1

- Base station decode for Mobile B:
  - Signal received: +3, -1, -1, +1, +1, -1, -3, +3
  - Mobile B's code: -1, +1, +1, -1, +1, +1, +1, -1
  - Product result: -3, -1, -1, -1, +1, -1, -3, -3
  - Sum of Product results: -12
  - Decode rule: For result near -8, data is binary 0

Channel Allocation Schemes 1/3

- Fixed channel allocation (FCA)
  - ➢Area partitioned into cells
  - ➢a number of channels are assigned to each cell according to some *reuse pattern* depending on desired signal quality
  - ➢changing traffic conditions, user distribution?
- Dynamic channel allocation (DCA)
  - ➢Set of channels allocated to a cell varies with time
  - ➢Provide flexibility and traffic adaptability
  - ➢A cell can borrow a channel(s) from neighboring cells (ensuring that borrowing does not lead to channel interference)
  - ➢Less efficient than FCA under high-load conditions

Channel Allocation Schemes 2/3

•Hybrid channel allocation (HCA)

•Divide set of channels into a *fixed* and *dynamic* set

•Channels in fixed set divided into subsets associated with each cell and allocated using fixed allocation

•Channels in dynamic set are available to all cells and are allocated using dynamic techniques when all the fixed channels are in use

Channel Allocation Schemes 3/3

•Centralized

Channel assigned by MSC (central controller)

•Distributed

•Channel selected by local BS from which call initiated or by the mobile

•BS controlled

➢BS keeps information about the current available channels in its vicinity

➢Channel availability information is updated by exchange of status information between base stations

Fixed Channel Allocation 1/2

•A set of nominal channels is permanently allocated to each cell for exclusive use

•Uniform channel utilization is efficient if traffic distribution is uniform (same number of channels in each cell)

•Non-uniform traffic may result in high call blocking in some cells, while others have a sizeable number of spare channels (poor channel utilization)

•Number of channels need to match load in a cell

•Non-uniform channel allocation

•Static borrowing

Fixed Channel Allocation 2/2

•Non-uniform channel allocation

➢Number of channels allocated to each cell depends on expected traffic profile in that cell

➢Minimize the average blocking probability in the entire system

•Static borrowing

➢Unused channels from lightly loaded cells are re-assigned to heavily loaded ones at distances which does not cause interference (>= minimum reuse distance)

➢Channels reassigned periodically in a scheduled (if traffic known in advance) or predictive manner (using measurements)

Channel Borrowing Schemes 1/2

•An acceptor cell that has used all its nominal channels can borrow free channels from neighboring cells (donors)

•When a channel is borrowed, several other cells are prohibited from using it (*channel locking*)

•Deal with *short tem allocation* of borrowed channels and once a call is completed the borrowed channel is returned to its nominal cell

•Channel borrowing schemes

➢Simple Any nominal channel in a cell can be borrowed for temporary use

➢Hybrid Two subsets (local channels and borrowable channels)

Channel Borrowing Schemes 2/2

Category	*Scheme*
Simple Channel Borrowing	• Simple Borrowing (*SB*) • Borrow from the Richest (*SBR*) • Basic Algorithm (*BA*) • Basic Algorithm with Reassignment (*BAR*) • Borrow First Available (*BFA*)
Hybrid Channel Borrowing	• Simple Hybrid Borrowing Scheme (*SHCB*) • Borrowing with Channel Ordering (*BCO*) • Borrowing with Directional Channel Locking (*BDCL*) • Sharing with Bias (*SHB*) • Channel Assignment with Borrowing and Reassignment (*CABR*) • Ordered Dynamic Channel Assignment with Rearrangement (*ODCA*)

Table 1: Channel Borrowing Schemes

Simple Channel Borrowing Schemes 1/2

•Simple borrowing

➢A nominal channel set is assigned to a cell as in FCA case

➢After all nominal channels are used, an available channel from a neighboring cell is borrowed (not causing interference)

•Borrow from Richest → A channel is borrowed from the cell with the most number of available channels for borrowing

•Basic algorithm → take from richest but in a way that reduces future call blocking probability in the cell that is mostly affected by the channel borrowing

•Basic algorithm with reassignment → transfer of a call from a borrowed channel to a nominal channel whenever a nominal channel becomes available

Simple Channel Borrowing Schemes 2/2

•Borrow first available

➢Select first candidate channel that it finds

➢Channels are divided into sets and then each of the sets is assigned to cells in a reuse pattern. Sets are numbered in sequence. Search the sets in a prescribed sequence

•Performance Evaluation → Adopting a simple test for borrowing yields performance results quite comparable to systems which perform exhaustive and complex search methods

Scheme	*Complexity*	*Flexibility*	*Performance* # of tests to locate borrowable channel
Borrow from the Richest (*SBR*)	Moderate	Moderate	Few
Basic Algorithm (*BA*)	High	Moderate	A lot
Basic Algorithm with Reassignment (*BAR*)	High	Moderate	A lot
Borrow First Available (*BFA*)	Low	Low	Very Few

Table 2: Comparison between *BFA*, *SBR*, *BA* and *BAR*

Hybrid Channel Borrowing Schemes

•Simple Hybrid Channel borrowing Strategy

➢Ratio of "local:borrowable" is determined a priori, depending on an estimation of traffic conditions

➢Ratio can be adapted in a scheduled or predictive manner

•Borrowing with channel ordering

➢dynamically vary local to borrowable ratio according to changing traffic conditions

➢First nominal channel has highest priority of being assigned to next local call

➢last nominal channel has the highest priority of being borrowed by neighboring cells

Comparison between FCA schemes

Scheme	*Complexity*	*Flexibility*	*Performance*
Simple FCA	low	low	• Better than Dynamic and Hybrid Borrowing in heavy traffic
Static Borrowing	low-moderate	moderate	• Better than FCA
Simple Channel Borrowing	moderate-high	high	• Better than FCA and Static Borrowing in light and moderate traffic
Hybrid Channel Borrowing	moderate	moderate	• Better than FCA in light and moderate traffic. • Better than Simple Channel Borrowing in heavy loads

Table 5: Comparison Between Fixed Channel Allocation Schemes

Dynamic Channel Allocation

•No fixed relationship between channels and cells

•All channels kept in a central pool and are assigned dynamically

•After a call is completed, its channel is returned to central pool

•Which channel to select?

➢Future blocking probability in the vicinity of the cell

➢Usage frequency of the candidate channel

➢Reuse pattern

➢Channel occupancy distribution under current traffic conditions

Dynamic Channel Allocation

•One classification

➢*Call by call DCA* → Channel assignment is based only on current channel usage conditions in the service area

➢*Adaptive DCA* → Channel assignment is adaptively carried out using information on the previous as well as the present channel usage conditions

•Another classification

➢Centralized (assignment by a centralized controller) or distributed DCA (allocation by BS or Mobile)

➢Examples of centralized: First available

➢Distributed: local information about current available channels in the cell's vicinity (Cell based) or signal strength measurements

Hybrid Channel Allocation

•Mixture of FCA and DCA schemes

•HCA with channel reordering

•HCA schemes were calls that cannot find an available channel are queued instead of being blocked

Handling Handoffs 1/2

•Caused by radio link degradation or initiated to avoid congestion

•If adjacent cells do not have enough channels to support handoff, call is blocked (call terminated)

•Handoff prioritizing schemes are channel assignment schemes that allocate channels to hand-off requests more readily than new calls

•Guard Channel Scheme

- ➢Reserve a number of channels for handoffs in each cell
- ➢Remaining channels can be used equally between handoffs and new calls
- ➢Usable with DCA (collection of channels used only for handoff requests)

Handling Handoffs 2/2

•Handoff queuing schemes

- ➢No new call is granted a channel before handoff requests in the queue are served
- ➢When power level received by BS <= *handoff threshold* → call queued for service from neighboring cell
- ➢Call queued until channel available or power level received by BS < *receiver threshold*
- ➢Call terminated if no channel found while *receiver threshold* attained

•New call queuing schemes

PSS99 1/8

•Distributed DCA algorithm

•A channel should not be concurrently used for more than one communication session in the same cell or neighboring cells

•Assume a reuse pattern of 3 cells

•Some of the wireless channels are used as control channels between the MH and MSS, others are communication channels

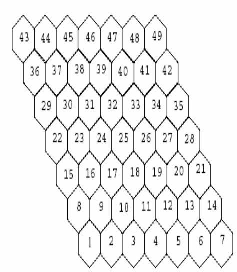


Figure 2: A 7×7 grid cellular system

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- MSS makes all channel allocation decisions on behalf of mobile hosts in its cell
- MSS requests to neighboring base stations are time-stamped
- To prevent selection of same channel → having selected a communication channel for transfer, based on a round of message exchange with its neighbors, MSS sends channel identity to its neighbors
  - If all neighboring MSS approve of selection, then transfer is performed
- *A newly acquired channel is not relinquished by a cell on completion of the communication session*, instead channel remains allocated to same cell until transfer to a neighboring cell

PSS99 3/8

- *Spectrum*

  all communication channels in the system. All channels are ordered. Channel with lowest frequency band is the first channel and the channel with the highest frequency band is the last channel
- $Allocate_i$

  set of channels allocated to C_i (initially empty)
- $Busy_i$

  a subset of $Allocate_i$, represents set of channels being used by C_i to support communication sessions
- $Transfer_i$

  set of channels earmarked for transfer from C_i to its neighbors

PSS99 4/8

(A) When a communication session is to be set-up in cell C_i, the following actions are taken by its mobile service station (MSS):

1. $T_i \leftarrow T_i + 1$;
2. $RT_i \leftarrow T_i$ /* RT_i has the timestamp of this channel request. */
3. If $Available_i \leftarrow Allocate_i - Busy_i - Transfer_i \neq \Phi$, then

   A highest order channel k from $Available_i$ is selected to set-up the session;

   $Busy_i \leftarrow Busy_i \cup \{k\}$;

   Go to step 10;

   else /* $Available_i = \Phi$ */

   Send timestamped REQUEST messages to each neighbor C_j.

PSS99 5/8

4. When C_i's MSS has received REPLY messages from each of its neighbors, containing their *Allocate, Busy and Transfer* sets, it takes the union of $Allocate_i$ and the *Allocate* sets received in the REPLY messages, and stores the result in $Interfere_i$.
5. If $Free_i \leftarrow Spectrum - Interfere_i \neq \Phi$, then a channel of the highest order is selected from $Free_i$ and added to $Allocate_i$. This channel is used to support the communication session. So, it is added to $Busy_i$ as well. Then go to step 10.
6. If $Free_i = \Phi$, it does not mean that no channel is available for allocation. Perhaps, the communication session can be supported by transferring a channel. C_i's MSS takes the union of $Busy_i$, $Transfer_i$, and $Busy$ and $Transfer$ sets received in the REPLY messages in step 4, and stores the result in $Interfere_i$.
7. If $Free_i \leftarrow Spectrum - Interfere_i = \Phi$, then the communication request is dropped. Otherwise, the channel of the lowest order in $Free_i$ is chosen for the transfer.

PSS99 6/8

8. Let the channel selected for transfer be k.
   $Busy_i \leftarrow Busy_i \cup \{k\}$;
   $Allocate_i \leftarrow Allocate_i \cup \{k\}$;
   C_i's MSS sends TRANSFER(k) messages to all the neighbors whose *Allocate* sets have k as a member and waits for replies. Let S denote the set of these neighbors.

9. If all the cells in S reply AGREED:

   Channel k is used to support the communication session.
   C_i's MSS sends RELEASE(k) messages to all the cells in S.
   Go to Step **10**.

   Otherwise: /* Some cells have sent REFUSE message. */

   $Allocate_i \leftarrow Allocate_i - \{k\}$;
   $Busy_i \leftarrow Busy_i - \{k\}$;
   C_i's MSS sends KEEP(k) messages to all the cells in S.
   C_i's MSS selects the next channel from $Free_i$, with order greater than that of k, and steps 8 and 9 are repeated. [2] To avoid excessive channel transfer overheads, under heavy load situations, the number of transfer attempts can be limited to the minimum of a THRESHOLD value (parameter of the algorithm) and the cardinality of $Free_i$. If all attempts to transfer a channel fail, the communication request is dropped.

PSS99 7/8

10. Once a cell has decided to drop a request or to use a channel to support the corresponding communication session:

    - it sends all the deferred REPLYs to its neighbors.
    - $RT_i \leftarrow 0$;

11. When a communication session terminates in C_i, the corresponding channel is deleted from the set $Busy_i$.

(B) When a cell C_j's MSS receives a REQUEST message from C_i's MSS with timestamp T_i:

PSS99 8/8

$T_j \leftarrow T_j + 1$;
$T_j \leftarrow \max(T_j, T_i + 1)$;

C_j's MSS sends a REPLY message to C_i if C_j is not requesting a channel (i.e. $RT_j = 0$), or if C_j is requesting a channel and C_i's request's timestamp is smaller than C_j's request's timestamp (i.e., $T_i < RT_j$ or $T_i = RT_j$ and $i < j$). Otherwise, the REPLY is deferred. As C_i only uses the union of the $Busy_j$ and $Transfer_j$ sets received in the REPLYs, in Step (A).6, and never uses the two sets separately, the communication overheads can be reduced by taking their union at C_j and sending the result, rather than both the sets, in the REPLY message. Therefore, the REPLY message contains $Allocate_j$, and the union of $Busy_j$, and $Transfer_j$.

(C) When a cell C_j's MSS receives TRANSFER(k) message from C_i:

If ($k \in Busy_j$) OR ($k \in Transfer_j$) then send REFUSE(k) message to C_i. Otherwise $Transfer_j \leftarrow Transfer_j \cup \{k\}$; Send AGREED($k$) message to C_i.

(D) When C_j's MSS receives a RELEASE(k) message, the following actions take place.

$Allocate_j \leftarrow Allocate_j - \{k\}$;
$Transfer_j \leftarrow Transfer_j - \{k\}$;

(E) When C_j's MSS receives KEEP(k) message, the following actions take place.

$Transfer_j \leftarrow Transfer_j - \{k\}$;